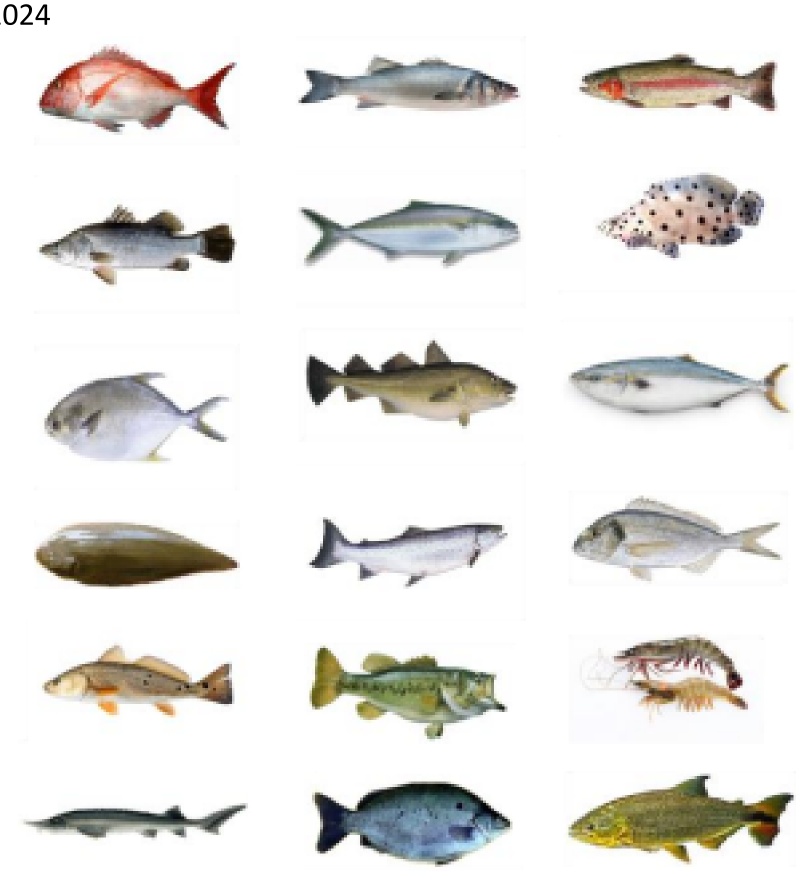
Fishmeal and fish oil-free aquafeeds:

A basic bibliography of studies highlighting carnivorous species

Produced by F3 Future of Fish Feed

May 2024



Overview

The following bibliography lists papers that center attention on replacing dietary fishmeal and fish oil from aquafeeds of carnivorous fishes. Each document provides strong evidence to support the contention that aquacultured carnivores do not require marine resources as essential components of their diet. Rather, it is the balance of essential nutrients, and ensuring that nutritional requirements are met that matters and, as attested by hundreds of studies, an ever-increasing list of alternative ingredients can satisfy these demands. The noted papers are not necessarily the definitive referencesfor a particular species, but they serve to provide entry into appropriate literature while also highlighting the wide variety of successful trials with marine resource-free diets. For convenience the listing commences with freshwater fishes, moves on to cultured marine teleosts and finishes with papers that deal with crustaceans. Contributions from f3fin collaborators (f3fin.org) are highlighted in bold. Interested readers are directed to the following reviews for further information:

Campbell, K.B., McLean, E. and Barrows, F.T. (2022). In pursuit of fish-free aquafeeds: a multi-species evaluation. Fishes, 7, 36. https://doi.org/10.3390/fishes7060336 and reprinted as: Paolucci, M. and Koshio, S. (Editors), *Fish Nutrition and Feed Technology*. MDPI, Basel, Switzerland. 258 pp.

McLean, E. (2023). Feed ingredients for sustainable aquaculture, pp. 392-423, In: Ferranti, P (editor), *Sustainable Food Science: A Comprehensive Approach*, volume 4, Elsevier Inc., https://doi.org/10.1016/B978-0-12-823960-5.00085-8.

Glencross, B., Ling, X., Gatlin, D.M., Kaushik, S., Øverland, M., Newton, R., Valente, L.M.P. (2024). A SWOT Analysis of the use of marine, grain, terrestrial-animal and novel protein ingredients in aquaculture feeds. Rev. Fish. Sci. Aquacult. https://doi.org/10.1080/23308249. 2024.2315049.

Rainbow trout

Rainbow trout, a species native to Kamchatka through the Pacific drainages of North America, has been introduced into waters on every continent except Antarctica. It has been cultured since the 18th century and is now farmed in over 70 countries with current production at around 940,000 tonnes per annum. There are well over 100 publications that have examined the responses of rainbow trout to fishmeal free diets. Trout are harvested as portion and large sizes (400-5000g) and strains are now available that readily accept plant-based diets. Indeed, fishmeal and fish oil free rainbow trout are already sold commercially in North America and Europe.

Gomes, E.F., Rema, P., Kaushik, S.J. (1995). Replacement of fish meal by plant proteins in the diet of rainbow trout (*Oncorhynchus mykiss*): digestibility and growth performance. Aquaculture 130, 177-186.

Adelizi, P.D., Rosati, R.R., Warner, K., Wu, Y.V., Muench, T.R., White, M.R., Brown, P.B. (1998). Evaluation of fish-meal free diets for rainbow trout, *Oncorhynchus mykiss*. Aquacult. Nutr. 4, 255-262.

Barrows, F.T., Gaylord, T.G., Sealey, W.M., Porter, L., Smith, C.E. (2008). The effect of vitamin premix in extruded plant-based and fish meal based diets on growth efficiency and health of rainbow trout, *Oncorhynchus mykiss*. Aquaculture 283, 148-155.

Barrows, F.T., Gaylord, T.G., Sealey, W.M., Smith, C.E., Porter, L. (2010). Supplementation of plant-based diets for rainbow trout (*Oncorhynchus mykiss*) with macro-minerals and inositol. Aquacult. Nutr. 16, 654-661.

Sealey, W.M., Hardy, R.W., Barrows, F.T., Pan, Q., Stone, D.A. (2011). Evaluation of 100% fish meal substitution with chicken concentrate, protein poultry by-product blend, and chicken and egg concentrate on growth and disease resistance of juvenile rainbow trout, *Oncorhynchus mykiss*. J World Aquac Soc 42, 46-55.

Welker, T., Barrows, F.T., Overturf, K., Gaylord, G., Sealey, W. (2016). Optimizing zinc supplementation levels of rainbow trout (*Oncorhynchus mykiss*) fed practical type fishmeal- and plant-based diets. Aquacult Nutr 22, 91-108.

Callet, T., Médale, F., Larroquet, L., Surget, A., Aguirre, P., Kerneis, T., Labbé, L., Quillet, E., Geurden, I., Skiba-Cassy, S., Dupont-Nivet, M. (2017). Successful selection of rainbow trout (*Oncorhynchus mykiss*) on their ability to grow with a diet completely devoid of fishmeal and fish oil, and correlated changes in nutritional traits. PLoS ONE 12(10): e0186705. https://doi.org/10.1371/journal.pone.0186705.

Roques, S., Deborde, C., Richard, N., Sergent, L., Kurz, F., Skiba-Cassy, S., Fauconneau, B., Moing, A. (2018). Characterizing alternative feeds for rainbow trout (*O. mykiss*) by 1H NMR metabolomics. Metabolomics 14, 155.

Brezas, A., Hardy, R.W. (2020). Improved performance of a rainbow trout selected strain is associated with protein digestion rates and synchronization of amino acid absorption. Sci Rep 10, 4678.

Gaudioso, G., Marzorati, G., Faccenda, F., Weil, T., Lunelli, F., Cardinaletti, G., Marino, G., Olivotto, I., Parisi, G., Tibaldi, E., Tuohy, K.M., Fava, F. (2021). Processed animal proteins from insect and poultry by-products in a fish meal-free diet for rainbow trout: impact on intestinal microbiota and inflammatory markers. Int. J. Mol. Sci. 10.3390/ijms22115454.

Betiku, O.C., Barrows, F.T., Ross, C., Sealey, W.M. (2016). The effect of total replacement of fish oil with DHA-Gold® and plant oils on growth and fillet quality of rainbow trout (*Oncorhynchus mykiss*) fed a plant-based diet. Aquacult. Nutr. 22, 158-169.

Huang, H., Li, X., Cao, K., Leng, X. (2023). Effects of replacing fishmeal with the mixture of cottonseed protein concentrate and Clostridium autoethanogenum protein on the growth, nutrient utilization, serum biochemical indices, intestinal and hepatopancreas histology of rainbow trout (*Oncorhynchus mykiss*). Animals 13, 817. https://doi.org /10.3390/ ani13050817.

Ruiz, A., Sanahuja, I., Thorringer, N.W., Lynegaard, J., Ntokou, E., Forones, D., Gisbert, E. (2023). Single cell protein from methanotrophic bacteria as an alternative healthy and functional protein source in aquafeeds, a holistic approach in rainbow trout (*Oncorhynchus mykiss*) juveniles. Aquaculture 576, 739861.

Hong, J., Bledsoe, J.W., Overturf, K.E., Hardy, R.W., Small, B.C. (2024). Balancing dietary plant-based lipids and cholesterol to increase fillet omega 3 deposition in rainbow trout (*Oncorhynchus mykiss*) fed a diet without animal ingredients. Aquaculture 578, 740029.

Kesbiç, O.S., Acar, Ü., Kesbiç, F.I., Yilmaz, S. (2024). Growth performance, health status, gut microbiome, and expression of immune and growth related genes of rainbow trout (*Oncorhynchus mykiss*) fed diets with pea protein replacement of fish meal. Comp Biochem Physiol B, 2024, 110968.

Largemouth bass

Global aquaculture production of largemouth bass closes in on 450,000 tonnes. Although farmed in half a dozen countries, it is China that accounts for over 95% of the output. This is extraordinary since fish were only introduced in the 1980s, and have started to supplant tilapia as a favored farmed fish due to its value and market potential.

McLean, E., Fredriksen, L., Alfrey, K., Craig, S. R., & Barrows, F. T. (2020). Performance of largemouth bass *Micropterus salmoides* (Lacépède, 1802), fed fishmeal- and fish oil-free diets. Int J Fish Aquat Stud 8, 6-10.

McLean, E., Fredriksen, L., Alfrey, K., Tlusty, M.F., Barrows, F. T. (2020). Growth, integrity, and consumer acceptance of largemouth bass, *Micropterus salmoides* (Lacépède, 1802), fed marine resource-free diets. Int J Fish Aquat Stud 8, 365-369.

Li, X., Zheng, S., Ma, X., Cheng, K., Wu, G. (2021). Use of alternative protein sources for fishmeal replacement in the diet of largemouth bass (*Micropterus salmoides*). Part I: effects of poultry by-product meal and soybean meal on growth, feed utilization, and health. Amino Acids 53, 33-47.

McLean, E., Alfrey, K., Gatlin, D.M. III, Barrows, F.T. (2022). Responses of largemouth bass to fishmeal and fish oil-free diets. Aquacult Res 53, 3036-3047.

Yellowtails

Yellowtail, or amberjack culture commenced in Japan during the 1920s when captive juveniles were held in coastal enclosures and fattened until large enough for the plate. Today, Japan produces around 150,000 tonnes which makes it one of their most cultivated fishes. Interest in the *farming of other species has grown considerably and include Californian yellowtail and greater amberjack. Commercial activity with hatchery-produced fish has commenced in Hawai'i and Malta and interest has been shown by companies in Spain, Greece and elsewhere.*

Watanabe, T., Aoki, H., Shimamoto, K., Hadzuma, M., Maita, M., Yamagata, Y., Kiron, V., Satoh, S. (1998). A trial to culture yellowtail with non fishmeal diets. Fish. Sci 64, 505-512.

Takagi, S., Murata, H., Goto, T., Endo, M., Yamashita, H., Ukawa, M. (2008). Taurine is an essential nutrient for yellowtail *Seriola quinqueradiata* fed non-fish meal diets based on soy protein concentrate. Aquaculture 280, 198-205.

Meigs, H., Barrows, F. T., Sims, N. A., Alfrey, K. (2020). Testing diets without fishmeal and fish oil for kampachi. Responsible Seafood Advocate 08/24/2020. https://www.globalseafood.org/advocate/ testing-diets-without-fishmeal-and-fish-oil-for-kampachi/ Stuart, K. R., Barrows, F. T., Silbernagel, C., Alfrey, K., Rotstein, D., Drawbridge, M. A. (2020). Complete replacement of fish oil and fish meal in the diet of juvenile California yellowtail *Seriola dorsalis*. Aquacult Res 52, 655-665.

Seong, T., Matsuyoshi, J., Haga, Y., Kabeya, N., Kitagima, R., Miyahara, J., Koshiishi, T., Satoh, S. (2021). Utilization of microalgae *Schizochytrium* sp. in non-fish meal, non-fish oil diet for yellowtail (*Seriola quinqueradiata*), Aquacult Res. 53, 2042-2052.

Red drum and Pompano

Pompano production globally exceeds 170,000 tonnes with the top producer being China. Other Asian producers, including those in India, Malaysia, Viet Nam, Indonesia, and the Philippines, have increased production of various of the 21 recognized species. Florida pompano has been identified as a species of interest for US aquaculture which is not too surprising given its market value and excellent characteristics as a candidate. Red drum is farmed commercially in Texas, Florida and Louisiana while other southern states evaluate the animal's potential. Production of red drum, which stands at around 80,000 tonnes globally, is also practiced in China, Mexico and Israel.

Suehs, B., Alfrey, K, Barrows, F., Gatlin, D.M. III (2022). Evaluation of growth performance, condition indices and body composition of juvenile red drum (*Sciaenops ocellatus*) fed fishmeal- and fish-oil-free diets. Aquaculture 551, 737961.

Alfrey, K.B., Gatlin, D.M. III, Barrows, F.T. and McLean, E. (2022). Assessment of open-source, fish-free diets for pompano, *Trachinotus carolinus* (Perciformes, Carangidae), under hyposaline conditions. Aquacult Res, in press.

Riche, M., Barrows, F.T., Nilles, Z., Alfrey, K. B., Wills, P. S. (2023). Replacement of fish oil with a high DHA algal oil in a fishmeal-free diet fed to Florida pompano *Trachinotus carolinus*. Front Aquac 2, https://doi.org/10.3389/faquc.2023.1163542.

Asian seabass-Barramundi

Approximately 100,000 tonnes of barramundi are produced annually with farms in Australia, Malaysia, Thailand, Taiwan the US and even Switzerland. At $16-20 per kg with firm white flesh, the popularity of barramundi has increased rapidly and due to its adaptability to various farming systems and low salinities the species offers considerable potential. First farmed in Thailand during the 1970s, nutritional research has demonstrated the potential of the species to accept marine resource-free diets.

Glencross, B., Blyth, D., Irvin, S., Bourne, N., Morton, K.M., Campet, M., Boisot, P., Wade, N.M. (2016). An evaluation of the complete replacement of both fishmeal and fish oil in diets for juvenile Asian seabass, *Lates calcarifer*. Aquaculture 451, 298-309.

Ma, Z., Hassan, M.M., Allais, L., He, T., Leterme, S., Ellis, A.V., McGraw, B., Qin, J.G. (2018). Replacement of fishmeal with commercial soybean meal and EnzoMeal in juvenile barramundi *Lates calcarifer*. Aquac. Res. M49, 3258-3269.

Hong, Y.C., Chu, J.H., Kirby, R., Sheen, S.S., Chien, A. (2021). The effects of replacing fish meal protein with a mixture of poultry by-product meal and fermented soybean meal on the growth performance and tissue nutritional composition of Asian seabass (*Lates calcarifer*). Aquacult Res 52, 4105-4115.

Santillan, E., Yasumaru, F., Vethathirri, R. S., Thi, S. S., Hoon, H. Y., Sian, D. C. P., & Wuertz, S. (2024). Microbial community-based protein from soybean-processing wastewater as a sustainable alternative fish feed ingredient. *Scientific Reports*, *14*(1), 1-11 [https://www.nature.com/articles/s41598-024-51737-w].

Cobia

Cobia is a fast-growing large marine pelagic that can attain 68 kg in weight. Their high-quality flesh has made them an excellent candidate species and presently commercial operations are ongoing in the US, Mexico, Belize and Panama as well as Taiwan, China and Vietnam. The species was one of the first marine carnivores in which success was achieved in completely replacing dietary fishmeal with plant proteins. Production in 2020 was approximately 53,000 tonnes.

Lunger, A.N., McLean, E., Gaylord, T.G., Kuhn, D., Craig, S.R. (2007). Taurine supplementation to alternative dietary proteins used in fish meal replacement enhances growth of juvenile cobia (*Rachycentron canadum*). Aquaculture, 271, 401–410.

Salze, G., McLean, E., Battle, P.R., Schwartz, M.H., Craig, S.R. (2010). Use of soy protein concentrate and novel ingredients in the total elimination of fish meal and fish oil in diets for juvenile cobia, *Rachycentron canadum*. Aquaculture 298, 294-299. Wang, J., Wu, G., Gatlin III, D.M., Lan, K., Wang, Y., Zhou, C., Ma, Z. (2024). Dietary fishmeal replacement by methanol-extracted cottonseed meal with amino acid supplementation for juvenile cobia *Rachycentron canadum*. J. Mar. Sci. Eng. 12, 235. https://doi.org/10.3390/jmse12020235

Red and gilthead sea bream and European sea bass

Gilthead seabream (GHS) is mainly produced in the Mediterranean and farm landings approach 260,00 tonnes per year. GHS has been produced using organically certified feeds with a production cost of around 8.60 €/kg. European sea bass (ESB) has been farmed in cages since the 1980s and in 2018, production stood at 235,000 tonnes with the major proportion of farmed ESB being derived from Turkey and Greece. Red sea bream (RSB) production in Japan stands above 65,000 tonnes, second only to yellowtail. Several trials have illustrated RSB ability to accept marine resource-free diets using a variety of alternative proteins and oils.

Torrecillas, S., Robaina, L., Caballero, M.J., Montero, D., Calandra, G., Mompel, D., Karalazos, V., Kaushik, S.J., Izquierdo, M.S. (2017). Combined replacement of fishmeal and fish oil in European sea bass (*Dicentrarchus labrax*): Production performance, tissue composition and liver morphology. Aquaculture 474, 101-112.

Seong, T., Kitagima, R., Haga, Y., Satoh, S. (2020). Non-fish meal, non-fish oil diet development for red sea bream, *Pagrus major*, with plant protein and graded levels of *Schizochytrium* sp.: Effect on growth and fatty acid composition. Aquacult. Nutr. 26, 1173-1185. Machado, M., Engrola, S., Colen, R., Conceição, L.E.C., Dias, J., Costas, B. (2020). Dietary methionine supplementation improves the European seabass (*Dicentrarchus labrax*) immune status following long-term feeding on fishmeal-free diets. Br. J. Nutr. 124, 890-902. Solé-Jimémez, P., Naya-Català, F., Piazzon, M.C., Estensoro, I., Calduch-Giner, J.A., Sitjà-Bobadilla, A., van Mullem, D., Pérez-Sánchez, J. (2021). Reshaping of gut microbiota in gilthead sea bream fed microbial and processed animal proteins as the main dietary protein source. Front. Mar. Sci. 8, 705041.

Seong, T., Uno, Y., Kitagima, R., Kabeya, N., Haga, Y., Satoh, S. (2021). Microalgae as main ingredient for fish feed: Non-fish meal and non-fish oil diet development for red sea bream, *Pagrus major*, by blending of microalgae *Nannochloropsis*, *Chlorella* and *Schizochytrium*. Aquacult Res. 52, 6025-6036.

Piazzon, M.C., Naya-Català, F., Pereira, G.V., Estensoro, I., Del Pozo, R., Calduch-Giner, J.A., Nuez-Ortín, W.G., Palenzuela, O., Sitjà-Bobadilla, A., Dias, J., Conceição, L.E.C., Pérez-Sánchez, J. (2022). A novel fish meal-free diet formulation supports proper growth and does not impair intestinal parasite susceptibility in gilthead sea bream (*Sparus aurata*) with a reshape of gut microbiota and tissue-specific gene expression

patterns. Aquaculture 558, 738362.
Takakuwa, F., Murashita, K., Noguchi, Y., Inui, T., Watanabe, K., Sugiyama, S., Yamada, S., Biswas, A., Tanaka, H. (2023). Effects of long-term feeding of fishmeal-free diet on growth parameters, bile acid status, and bile acid-related gene expression of yearling red sea bream *Pagrus major* (Temminck & Schlegel, 1843). Aquaculture 570, 739444.
Randazzo, B., Di Marco, P., Zarantoniello, M., Daniso, E., Cerri, R., Finoia, M.G., Capoccioni, F., Tibaldi, E., Olivotto, I., Cardinaletti, G. (2023). Effects of supplementing a plant protein-rich diet with insect, crayfish or microalgae meals on gilthead sea bream (Sparus aurata) and European seabass (*Dicentrarchus labrax*) growth, physiological status and gut health. Aquaculture 575, 739811.
El-Dakar, A.Y., Shalaby, S.M., Osman, M.F., Mohammed, A.S.H. (2023). Nutritional evaluation of fishmeal free diets in European seabass, *Dicentrarchus labrax*, feeds reared in fresh water. J. Aquat. Sci. Fish Resourc. 4, 1-15.

Atlantic salmon

Around 2 million tonnes of salmon are farmed each year with most of the production being in two countries: Norway and Chile, but large quantities coming from Canada and Scotland. The salmon feed industry has reduced its fishmeal (65→18%) and fish oil (24→11%) usage substantively since the mid-1990s by increasing the use of by-products, novel oils and improving feed conversion efficiencies. Yet, due to its size, the industry still takes the lion's share of global fishmeal production – around 23%, and 60% of all fish oil. A building body of evidence reveals that salmon can thrive of available alternatives.

Davidson, J., Barrows, F.T., Kenney, P.B., Good, C., Schroyer, LK., Summerfelt, S.T. (2016). Effects of feeding a fishmeal-free versus a fishmeal based diet on post-smolt Atlantic salmon *Salmo salar* performance, water quality, and waste production in recirculation aquaculture systems. Aquacult Eng 74, 38-51.
Davidson, J., Kenney, P.B., Barrows, F.T., Good, C., Summerfelt, S.T. (2016). Fillet quality and processing attributes of postsmolt Atlantic salmon, *Salmo salar*, fed a fishmeal-free diet and a fishmeal-based diet in recirculation aquaculture systems. J. World Aquacult Soc. 49, 183- 196.
Kousoulaki, K., Sveen, L., Norén, F., Espmark, Å. (2022). Atlantic salmon (*Salmo salar*) performance fed low trophic ingredients in a fish meal and fish oil free diet. Front. Physiol. 13, 884740. doi.org/10.3389/fphys.2022.884740.
Barrows, F.T., Campbell, K.B., Gaylord, T.G. and McLean, E. (2023). Influence of krill meal on performance of post-smolt Atlantic salmon fed fishmeal and fish oil-free diets. Fishes, 8, 590. https://doi.org/10.3390/fishes8120590. 1
McLean, E., Campbell, K.B., Kuhn, D., Tlusty, M.F. and Barrows, F.T. (2024). The impact of marine resource-free diets on quality attributes of Atlantic salmon. Fishes 9, 37. https://doi.org/10.3390/fishes9010037.

Miscellaneous species

The importance underlying the drive to replace the increasingly scarce and expensive fishmeal and fish oil component from aquafeeds is no better emphasized by the fact that dozens more species than those normally encountered, have been assessed for their responsiveness to such substitutions. These include freshwater, brackish, and marine examples and fish known and uncommon. Although varying degrees of success have been reported, each species examined responded positively, albeit with some expressing decreased growth performance.

Wang, Y., Kong, L.J., Li, C., Bureau, D.P. (2006). Effect of replacing fish meal with soybean meal on growth, feed utilization and carcass composition of cuneate drum (*Nibea miichthioides*). Aquaculture 261, 1307-1313.
Shapawi, R., Ng, W.-K., Mustafa, S. (2007). Replacement of fish meal with poultry by-product meal in diets formulated for the humpback grouper, *Cromileptes altivelis*. Aquaculture 273, 118-126.
Hansen, A., Rosenlund, G., Karlsen, O., Koppe, W., Hemre, G.-I. (2007). Total replacement of fish meal with plant proteins in diets for Atlantic cod (*Gadus morhua* L.) I - effects on growth and protein retention. Aquaculture, 272, 599-611.
Silva, J., Espe, M., Conceição, L., Dias, J., Valente, L. (2009). Senegalese sole juveniles (*Solea senegalensis* Kaup, 1858) grow equally well on diets devoid of fish meal provided the dietary amino acids are balanced. Aquaculture, 296, 309-317.
Zhu, H., Gong, G., Wang, J., Wu,X., Xue, M., Niu, C., Guo, Y. (2011).Replacement of fish meal with a blend of rendered animal protein in diets for Siberian sturgeon (*Acipenser baerii* Brandt), results in performance equal to fish meal fed fish. Aquacult Nutr 17, e389-e395. Twibell, R.G., Gannam, A.L., Hyde, N.M., Holmes, J.S.A., Poole, J.B. (2012). Effects of fish meal- and fish oil-free diets on growth responses and fatty acid composition of juvenile coho salmon (*Oncorhynchus kisutch*). Aquaculture 360–361, 69-77.
Hansen, A., Hemre, G.-I. (2013). Effects of replacing fish meal and oil with plant resources in on-growing diets for Atlantic cod *Gadus morhua* L. Aquacult. Nutr. 19, 641-650.
Van Hoestenberghe, S., Fransmann, C.A., Luyten, T., Vermeulen, D., Roelants, I., Buysens, S., Goddeeris, B.M. (2016). *Schizochytrium* as a replacement for fish oil in a fishmeal free diet for jade perch, *Scortum barcoo* (McCulloch & Waite). Aquacult. Res. 47, 1747-1760. Li, X., Qin, C., Fang, Z., Sun, X., Shi, H., Wang, Q., Zhao, H. (2022) Replacing dietary fish meal with defatted black soldier fly (*Hermetia illucens*) larvae meal affected growth, digestive physiology and muscle quality of tongue sole (*Cynoglossus semilaevis*). Front. Physiol. 13, 855957. doi: 10.3389/fphys.2022.855957.
Lorez, E.K., Sabioni, R.E., Volkoff, H., Cyrino, J.E.P. (2022). Growth performance, health, and gene expression of appetite-regulating hormones in Dourado *Salminus brasiliensis*, fed vegetable-based diets supplemented with swine liver hydrolysate. Aquaculture 548, Pt. 2, 737640.

Tiger and Pacific whiteleg shrimp

On a production basis, shrimp feeds are the number one user of fishmeal and fish oil yet numerous studies have demonstrated the lack of effect of marine resource-free diets on the growth of black tiger prawns and Pacific whiteleg shrimp. Moreover, alternative ingredient-based diets do not impact consumer acceptance, color or resistance to disease when challenged with known pathogens. Trials from the laboratory have been transferred to commercial-sized ponds with considerable success.

Sudaryono, A., Tsvetnenko, E., Evans, L.H. (1999). Evaluation of potential of lupin meal as an alternative to fish meal in juvenile *Penaeus monodon* diets. Aquac. Nutr. 5, 277-285.
McLean, E., Reid, B., Fegan, D., Kuhn, D. and Craig, S.R. (2006). Total replacement of fishmeal with an organically certified yeast-based protein in Pacific white shrimp (*Litopenaeus vannamei*) diets: Laboratory and field trials. Ribarstvo 64, 47-58.
Glencross, B., Irvin, S., Arnold, S., Blyth, D., Bourne, N., Preston, N. (2014). Effective use of microbial biomass products to facilitate the complete replacement of fishery resources in diets for the black tiger shrimp, *Penaeus monodon*. Aquaculture 431, 12-19. Simon, C.J., Truong, H., Habilay, N., Hines, B. (2021). Feeding behaviour and bioavailability of essential amino acids in shrimp *Penaeus monodon* fed fresh and leached fishmeal and fishmeal-free diets. Animals 11, 847. https://doi.org/10.3390/ani11030847. **McLean, E., Tran, L.H., Craig, S.R., Alfrey, K. and Barrows, F.T. (2020). Complete replacement of fishmeal by soybean and poultry meals in whiteleg shrimp feeds: Growth and tolerance to EMS/AHPND and WSSV challenge. Aquaculture 527, 735383.** Amador, A., Tinajero, A., Viana, M.T., Braga, A. (2022). Use of threonine fermentation biomass as an alternative replacement of fishmeal in fish free diets for *Litopenaeus vannamei* juveniles: The effects on growth performance and apparent digestibility. Aquacult. Res. 53, 2970-2974. **Tran, L.H., Nhut, T.C., Alfrey, K.B., Barrows, F.T., Kuhn, D., McLean, E. (2022). Performance of Pacific whiteleg shrimp fed a fishmeal and fish oil-free diet under commercial conditions. Int. J. Fish. Aquat. Stud. 10, 33-41.**
Coelho, R., Tacon, A.G.J. & Lemos, D. (2024). Effect of dietary phytase and protease supplementation on the growth performance and apparent nutrient digestibility in juvenile Pacific white shrimp (*Litopenaeus vannamei*) fed fish meal–free and phosphorus limiting diets. Aquacult. Int. https://doi.org/10.1007/s10499-024-01455-x.
Kuo, Y.C., Ho, T.H., Bharadwaj, A., Tran, H.T.Q., Chu, Y.T., Wang, S.H., Chen, T.Y., Nan, F.H., Lee, P.T. (2024). Feasibility assessment of replacing

fishmeal with *Clostridium autoethanogenum* protein in commercial whiteleg shrimp diets: Impacts on growth, muscle characteristics, and health. Anim. Feed Sci. Technol. 309, 115916.